Network Reliability

SI PROJECT

M2 SIA

Heni Walha | Gestion SI| 13/01/2024

heniwalha16/Network-Reliability-Project- (github.com)

Table of Contents

I. Main indicators

- The indicators are divided into 4 categories as the paper shows:

1. Statistical Range Methods
2. Buffer Time Methods
3. Tardy Trip Measures
4. Probabilistic Measures

1. STATISTICAL RANGE METHODS:

- Standard Deviation (STD): measures the spread of variability in travel time around the mean. Showing how much individual travel times are far from the average.
- Coefficient of Variation (COV): It's the ratio of the STD to the mean travel time. Providing normalized measure.

deviation is defined as

$$STD = \sqrt{\frac{1}{N-1}\sum_N (TT_i - M)^2}$$

while coefficient of variation is written as

$$COV = \frac{STD}{M}$$

- Skewness $\lambda^{skew}$and Width λ^{var} Indicators:
  - Skewness measures the asymmetry of the travel time distribution. Width indicators measure the spread and width of the travel time distribution.
  - Larger values of skewness and width indicate less reliable travel times.
  - Useful for understanding the probability of extreme travel times in relation to the median.

- User Index (UI): It has both skewness and width of the travel time distribution in the route length (Lr). It offers a measure that accounts for both distribution width and asymmetry, providing insights into travel time reliability from the user's standpoint.

$$\lambda^{var} = \frac{TT_{90} - TT_{10}}{TT_{50}}$$

$$\lambda^{skew} = \frac{TT_{90} - TT_{50}}{TT_{50} - TT_{10}}$$

$$UI_r = \frac{\lambda^{var} \ln(\lambda^{skew})}{L_r}$$

2. BUFFER TIME METHODS:

- Buffer Time (BT): Buffer time (BT) is the extra time users add to the average travel time for on-time arrival 95% of the time. It is a response to the unpredictable nature of travel conditions.

- Buffer Indicator (BI): It is the ratio of buffer time to the average travel time, useful for users to assess extra time needed for uncertainty in travel conditions. Answers questions like "What is the appropriate time margin?" or "When should I commence my journey?" or "How much time should I allow?"

$$BI = \frac{TT_{95} - M}{M}$$

3. TARDY TRIP MEASURES:

- Planning Time (PT): is the total time needed to plan for on-time arrival 95% of the time. This metric shows the meticulous planning to accommodate for potential delays.

- Planning Time Index (PTI): It is the ratio of the 95th percentile travel time to free-flow travel time. It signifies the planning duration essential for a 95% assurance of arriving on schedule. By referencing the 95th percentile value, this index explicitly considers extreme delays in travel time.

$$PTI = \frac{TT_{95}}{TT_{free\_flow}}$$

- Misery Index (MI): calculates the relative distance between the mean travel time of the 20% most unlucky travelers and the mean travel time of all travelers. This index Evaluates the impact on the unluckiest travelers and provides insight into the relative discomfort experienced by a subset of users. Specifically, those facing the 80th percentile travel time.

$$MI = \frac{M|_{TT_i > TT_{80}} - M}{M}$$

4. PROBABILISTIC MEASURES:

- Probabilistic Indicators (Pr):
  - Calculates the probability that travel times occur within a specified interval of time more than β minutes the median travel time.
  - Parameterized to differentiate between reliable and unreliable travel times.
  - Useful for presenting policy goals, such as the Dutch target for reliability.

$$\Pr\,(TT_i \geq \beta + TT_{50})$$

5.OVERALL ANALYSIS:

The indicators cover various aspects of reliability from both network operator and user perspectives.

They provide a comprehensive view of travel time variability, addressing different characteristics of the travel time distribution.

Each indicator serves a specific purpose, offering insights into different dimensions of reliability.

The emphasis on user-centric indicators, such as Buffer Index and Planning Time, reflects the importance of addressing travelers' concerns and uncertainties.

6. CALCULATIONS:

Dijikstra algorithm:

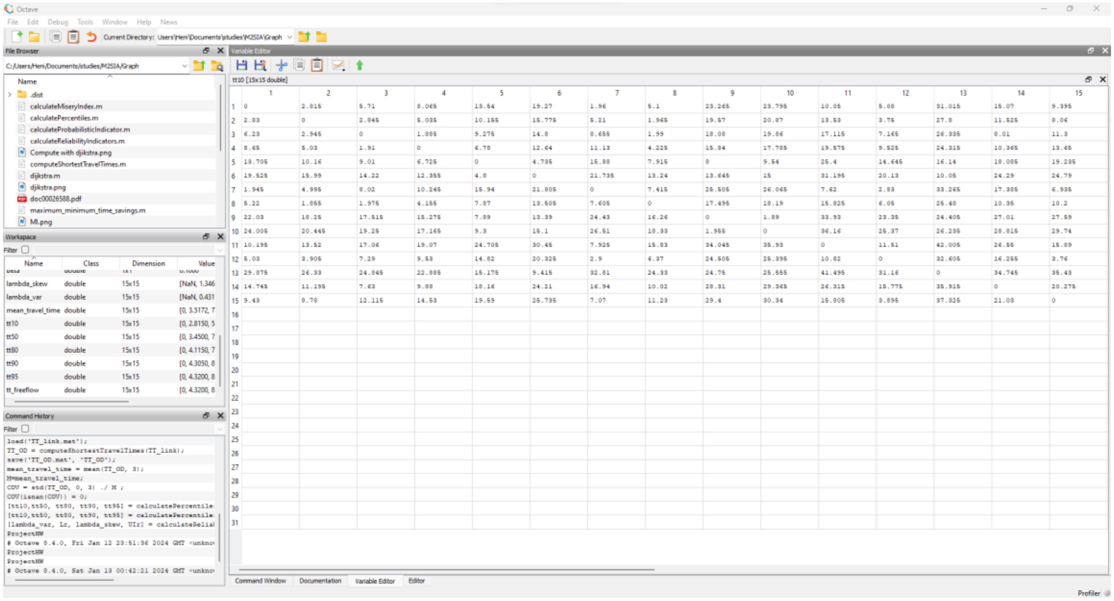
```matlab
% Dijkstra's algorithm function
function [distances, paths] = dijkstra(graph, start)
    num_nodes = size(graph, 1);
    distances = inf(1, num_nodes);
    paths = zeros(1, num_nodes);

    visited = false(1, num_nodes);
    distances(start) = 0;

    for i = 1:num_nodes
        current = -1;
        % Find the unvisited node with the smallest distance
        for j = 1:num_nodes
            if ~visited(j) && (current == -1 || distances(j) < distances(current))
                current = j;
            end
        end

        visited(current) = true;

        % Update distances and paths
        for j = 1:num_nodes
            if graph(current, j) > 0
                if distances(current) + graph(current, j) < distances(j)
                    distances(j) = distances(current) + graph(current, j);
                    paths(j) = current;
                end
            end
        end
    end
end
```

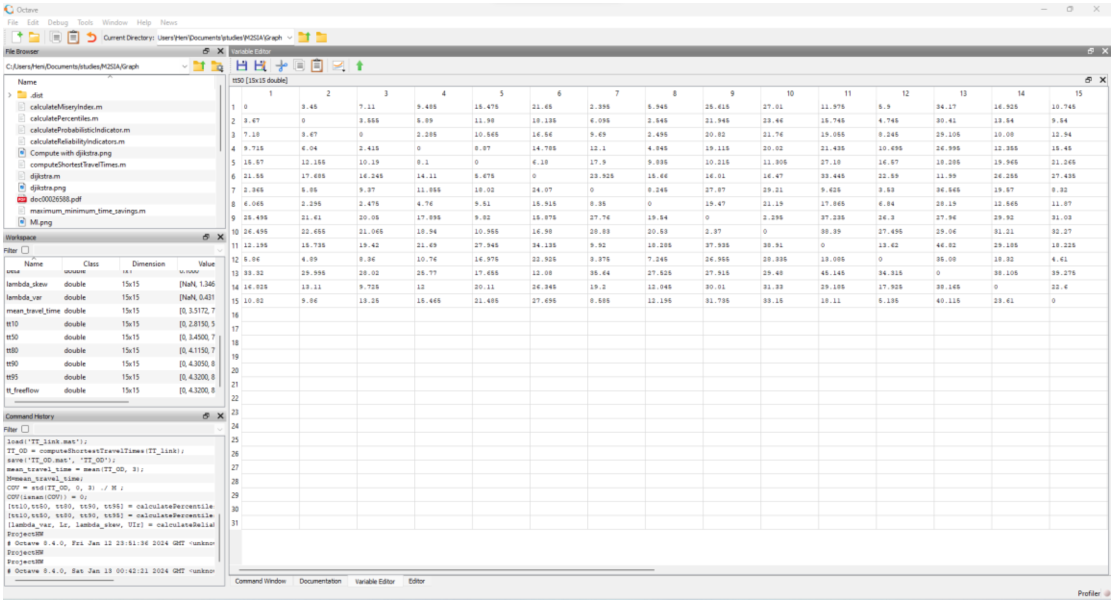
Compute TT_OD:

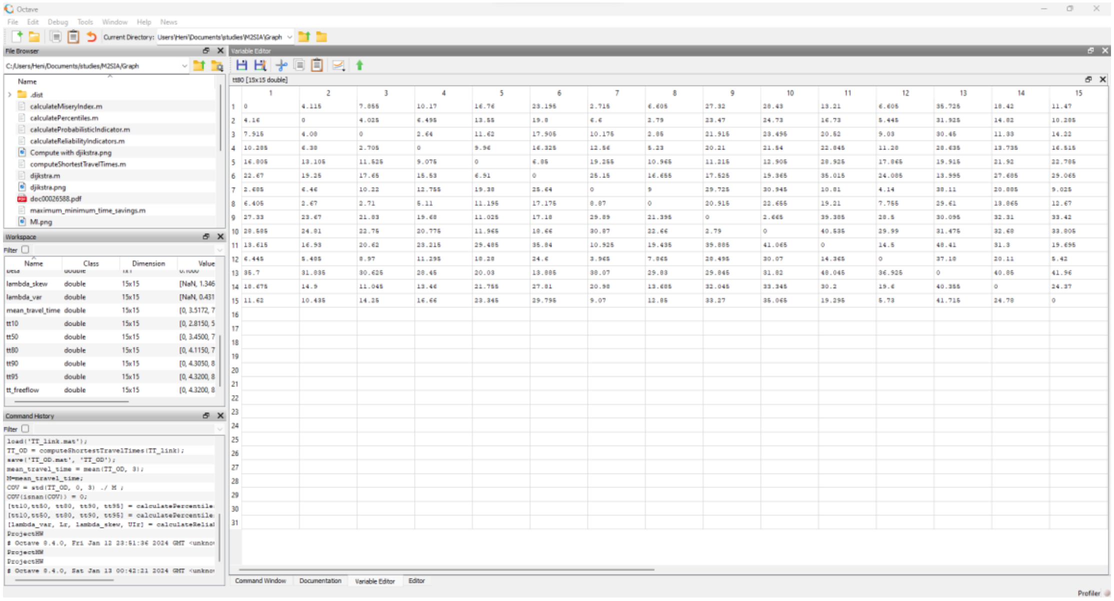
```matlab
function TT_OD = computeShortestTravelTimes(TT_link)
    % Number of bus stops
    num_stops = size(TT_link, 1);

    % Initialize the TT_OD matrix to store shortest travel times from any origin to any destination
    TT_OD = zeros(num_stops, num_stops, size(TT_link, 3));

    % Iterate over the 3rd dimension of TT_link (50 samples)
    for sample = 1:size(TT_link, 3)
        % Build the adjacency matrix for the current sample
        adjacency_matrix = squeeze(TT_link(:, :, sample));

        % Compute shortest travel times and paths using Dijkstra's algorithm
        for origin = 1:num_stops
            [distances, ~] = dijkstra(adjacency_matrix, origin);
            TT_OD(origin, :, sample) = distances;
        end
    end
end
```

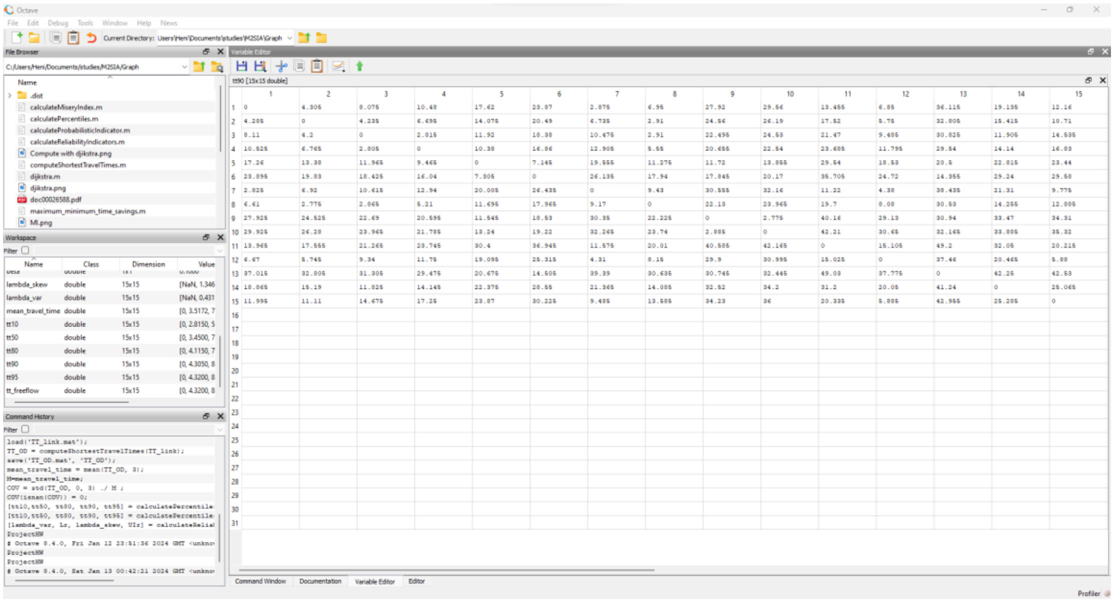
Compute percentiles:

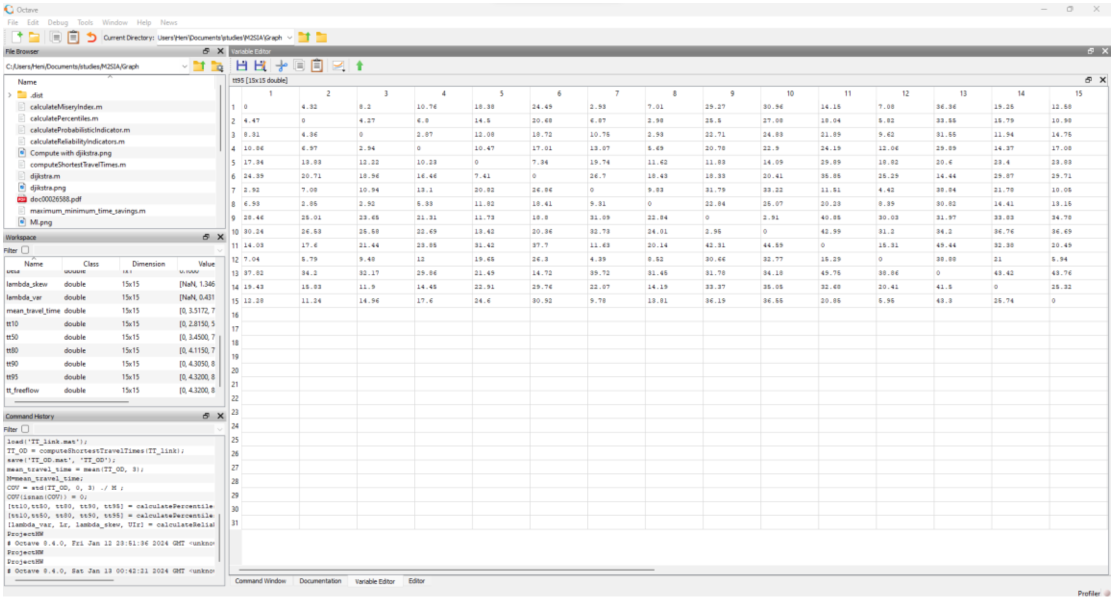
```matlab
function [tt10,tt50, tt80, tt90, tt95] = calculatePercentiles(TT_OD)
    % TT_OD: 3D matrix of travel times (origin, destination, sample)

    % Compute Percentiles
    tt10 = prctile(TT_OD, 10, 3);
    tt50 = prctile(TT_OD, 50, 3);
    tt80 = prctile(TT_OD, 80, 3);
    tt90 = prctile(TT_OD, 90, 3);
    tt95 = prctile(TT_OD, 95, 3);

end
```


Octave
Variable Editor
tt10 [15x15 double]


Octave
Variable Editor
tt50 [15x15 double]


Octave
File Browser
Variable Editor
Workspace
Command History
Command Window
Documentation
Variable Editor
Editor


Octave
File Browser
Variable Editor
Workspace
Command History
Command Window
Documentation
Variable Editor
Editor



Travel Time Percentiles (Minutes):

tt10: 10th percentile travel time

tt50: 50th percentile (median) travel time

tt80: 80th percentile travel time

tt90: 90th percentile travel time

tt95: 95th percentile travel time

Observations:

Travel times generally increase from tt10 to tt95, reflecting the distribution of travel times.

The values in the matrix represent the time it takes to travel between different origin-destination pairs, considering different percentiles.

Comparison for Regular and Occasional Users:

Regular User Perspective:

May be interested in tt50 (median) for typical travel time.

tt80 and tt90 can provide insights into potential delays for more cautious planning.

tt95 indicates the extreme upper limit, useful for contingency planning.

Occasional User Perspective:

May be more concerned with worst-case scenarios, so tt95 is crucial for extreme travel time considerations.

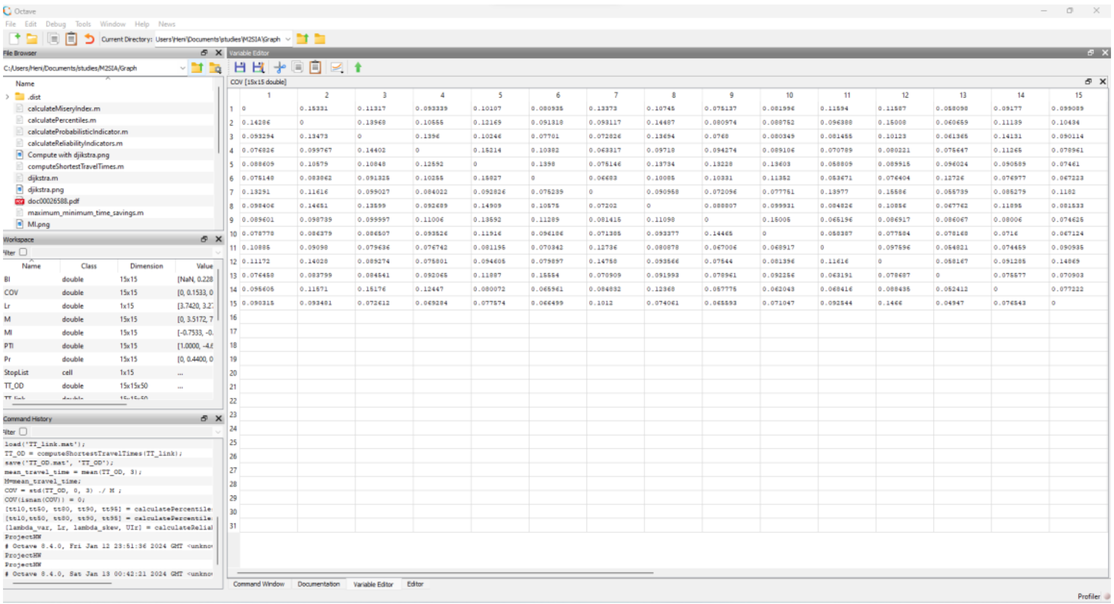
tt80 and tt90 still provide information on potential delays.

tt50 can give a sense of the typical travel time for occasional trips.

- If you were a regular user, you might focus on tt50, tt80, and tt90 for balanced planning.
- If you were an occasional user, you might prioritize tt95 for worst-case scenarios.

Compute COV:

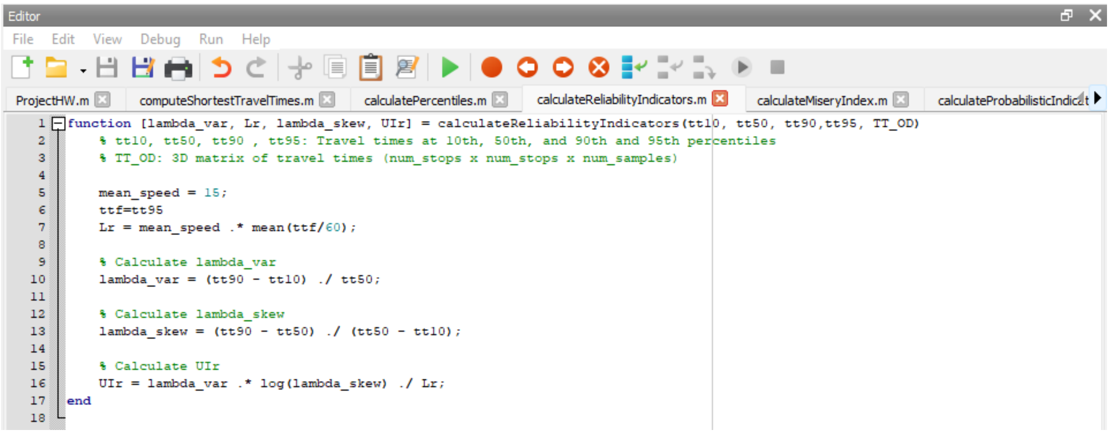
```
% Compute mean travel time (M)
mean_travel_time = mean(TT_OD, 3);
M=mean_travel_time;
COV = std(TT_OD, 0, 3) ./ M ;
COV(isnan(COV)) = 0;
```

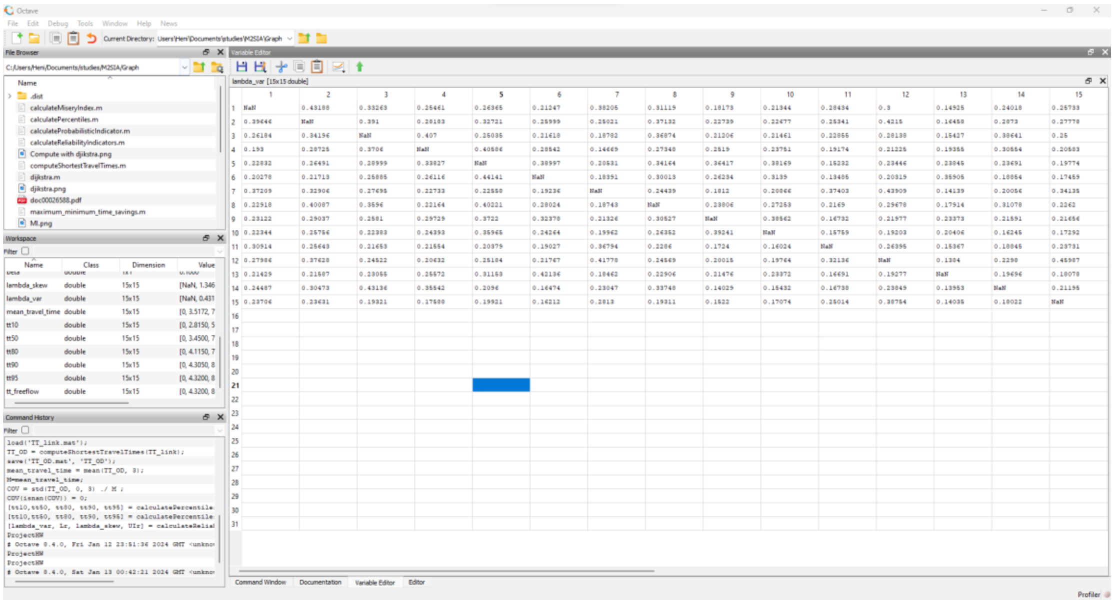


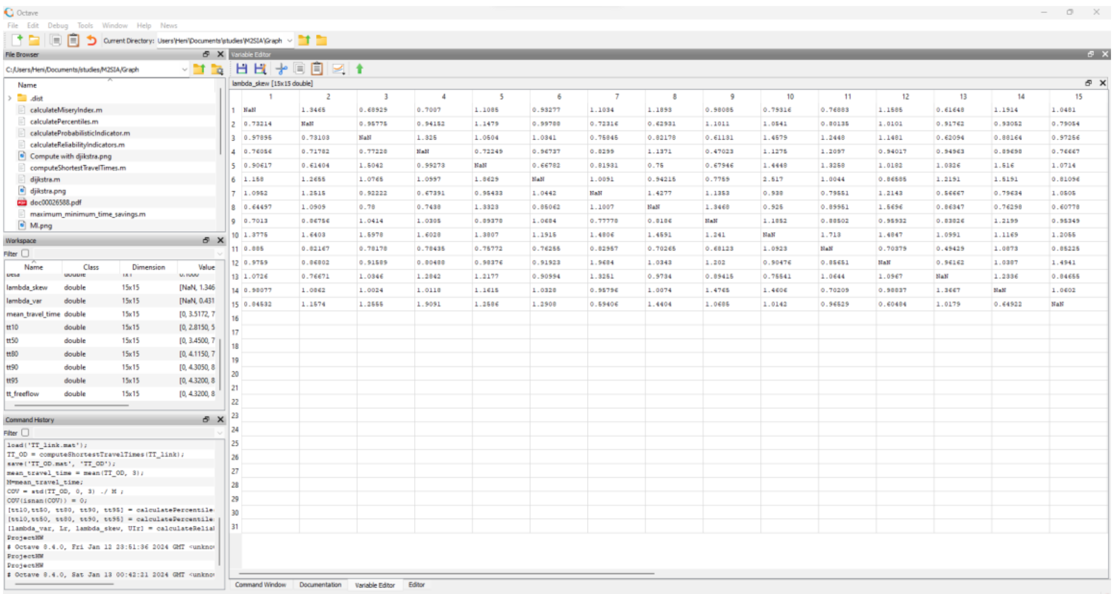
A positive covariance indicates that the two variables tend to increase or decrease together.

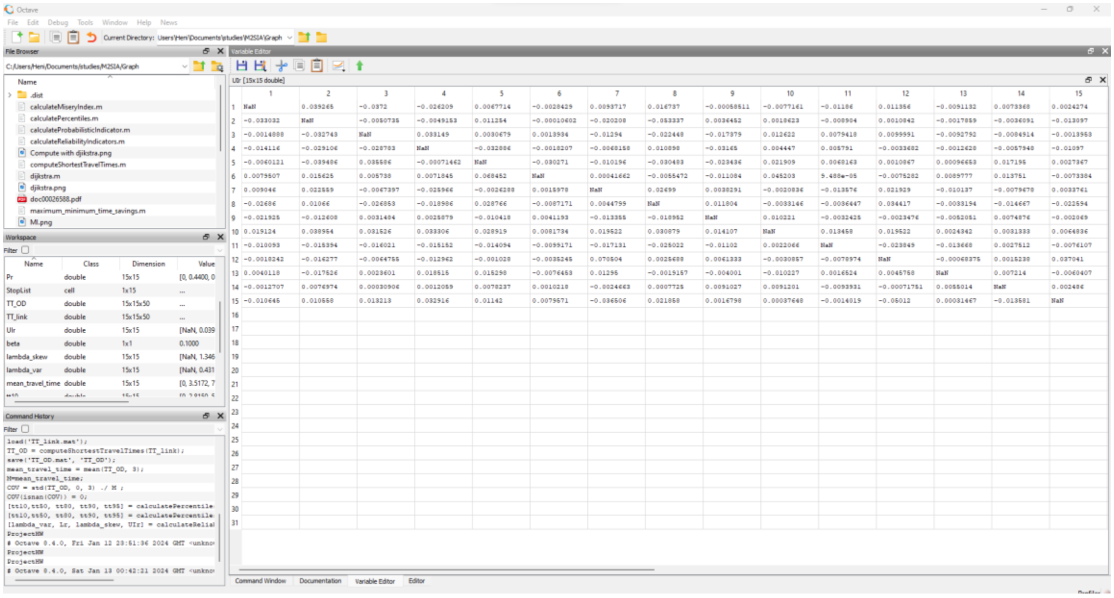
A negative covariance indicates that one variable tends to increase when the other decreases.

Compute Skewness λ^{skew}, Width λ^{var} and UI:









Skewness (lambda skew):

A positive skew indicates a longer right tail, while a negative skew indicates a longer left tail.

For regular users, look for low skewness, indicating a more symmetric distribution. Occasional users may tolerate slightly higher skewness, depending on the nature of the data.

Variance (lambda var):

For regular users, lower variance may be preferred as it suggests less variability. Occasional users might tolerate higher variance.

Look for patterns in variance across different scenarios or time periods.

User Interaction (UI):

Positive UI values suggest increased engagement, while negative values suggest reduced engagement.

Regular users might prefer consistently positive UI values, indicating sustained engagement. Occasional users may tolerate occasional dips in engagement.

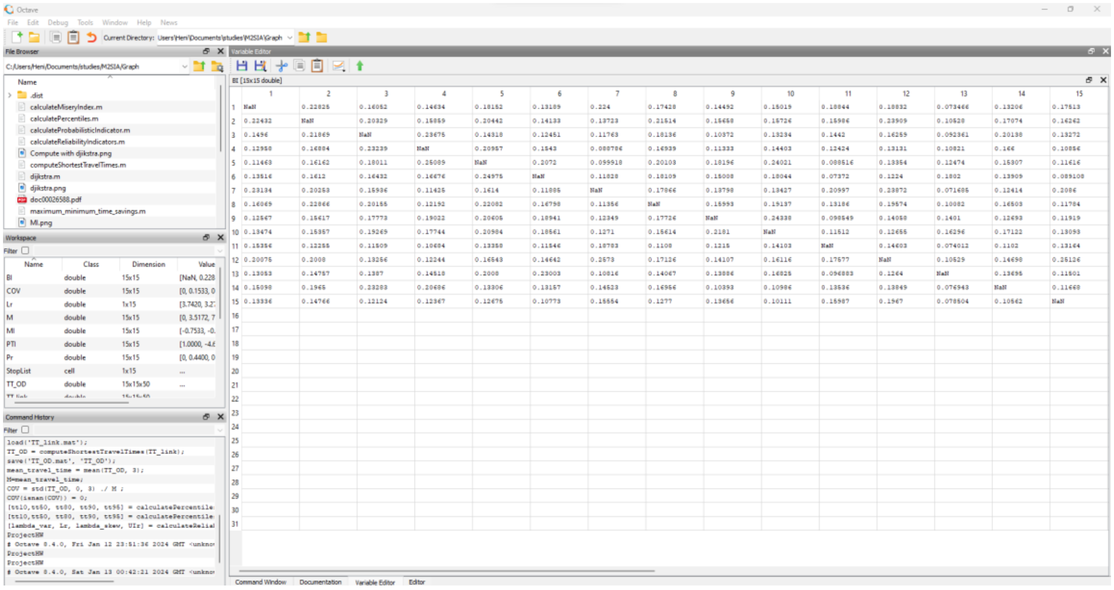
In summary, for each metric:

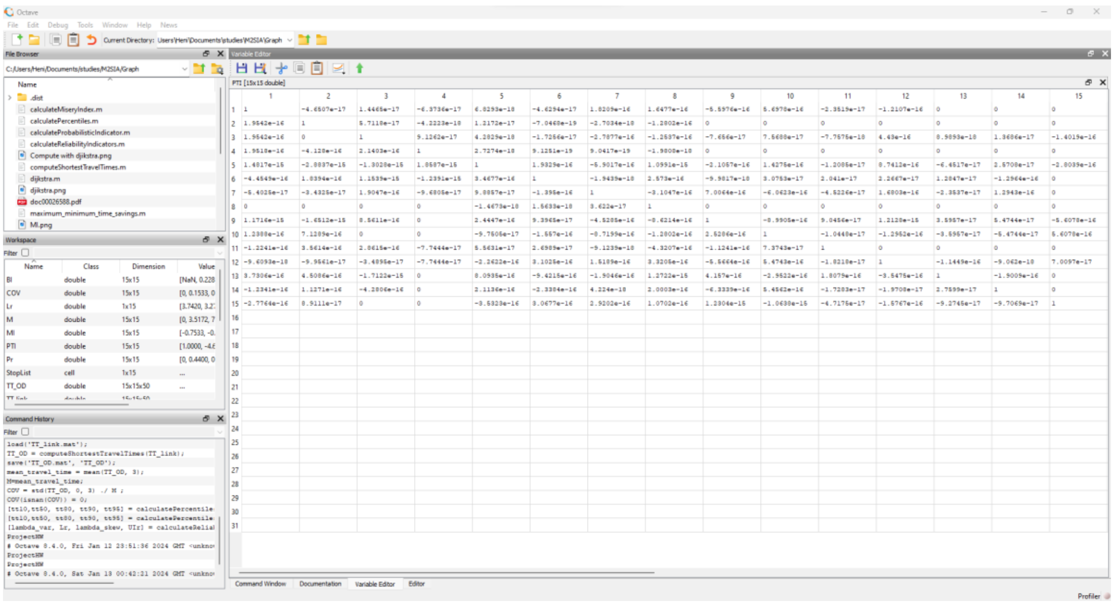
- Skewness: Regular users may prefer lower skewness for a more consistent experience. Occasional users might tolerate higher skewness, but it depends on their preferences.
- Variance: Regular users may prefer lower variance for more predictable experiences. Occasional users might tolerate higher variance, but it depends on the nature of the application or service.

- User Interaction: Both regular and occasional users would generally prefer positive UI values, but regular users may place a higher emphasis on sustained positive engagement.

Compute BI and PTI:

```
BI = (tt95 - M) ./ M;
tt_freeflow=tt95;
PTI = tt95 / tt_freeflow;
```





Buffer Indicator (BI) Results:

Regular Users:

Focus on values closer to 0.2, indicating a proportionate buffer to average travel time.

May prioritize a consistent and moderate buffer to account for uncertainties without excessive time allocation.

May look for patterns in the matrix to gauge how well the buffer aligns with different travel conditions.

Occasional Users:

May find extreme values (either high or low) more noticeable and potentially more useful.

Higher values (approaching 0.25) might indicate a more cautious approach, suitable for occasional users who may not be familiar with travel conditions.

Planning Time Index (PTI) Results:

Regular Users:

Look for values closer to 1, indicating that the planning time aligns with the free-flow travel time.

Values close to 0 suggest a potential underestimation of planning time, while values significantly above 1 suggest overestimation.

May appreciate a consistent and reliable measure that reflects extreme delays in travel time.

Occasional Users:

May benefit from an index that explicitly considers extreme delays (values significantly above 1).

Could use the PTI to understand the planning duration necessary for a high assurance (95%) of arriving on schedule.

Conclusion:

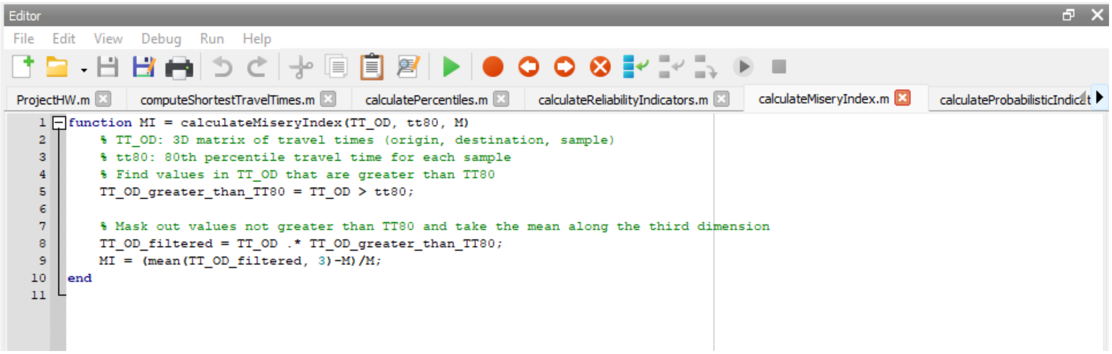
Buffer Indicator (BI):

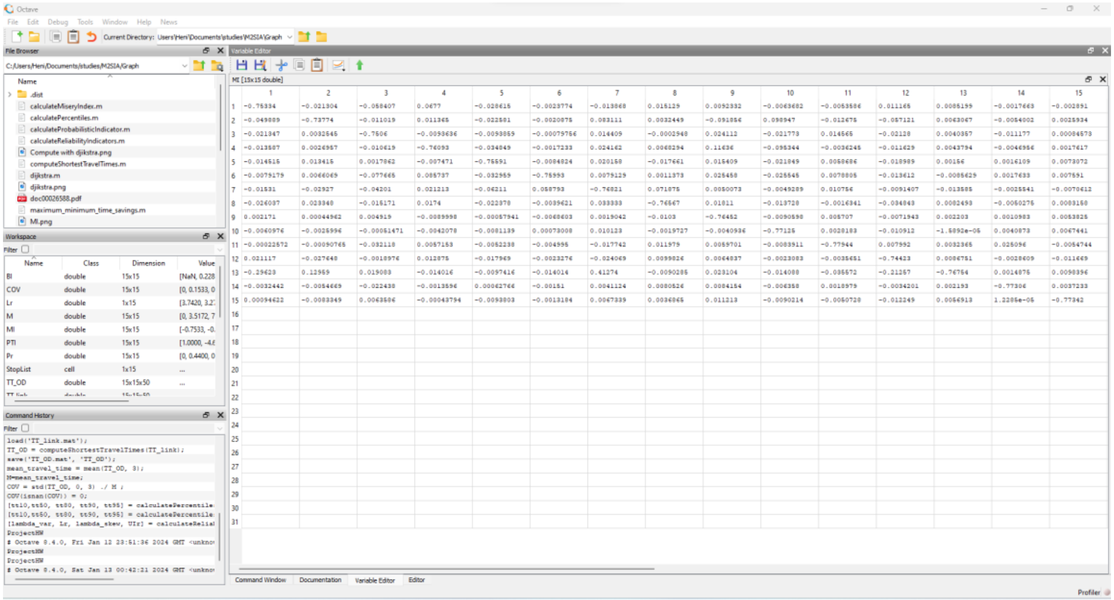
Regular users might prefer values around 0.2 for a balanced buffer, while occasional users might notice and adapt to extreme values.

Planning Time Index (PTI):

Regular users may favor values close to 1 for consistent planning, while occasional users may appreciate the explicit consideration of extreme delays.

Compute MI:





Regular Users:

May be interested in values close to zero or positive, as this would indicate a smaller gap between the mean travel time of the least fortunate 20% and the overall mean travel time.

Positive values might indicate a relatively consistent and manageable experience for the less fortunate travelers.

A decrease in the Misery Index could be seen as an improvement in the travel conditions for the least fortunate group.

Occasional Users:

May find extreme negative values interesting, as this suggests that the least fortunate travelers experience significantly lower mean travel times compared to the overall mean.

Extreme negative values might indicate that the least fortunate travelers experience less misery in terms of travel time than the average traveler.

Occasional users might focus on the overall trend in Misery Index to understand whether the travel conditions for the least fortunate are consistently better or worse.

Conclusion:

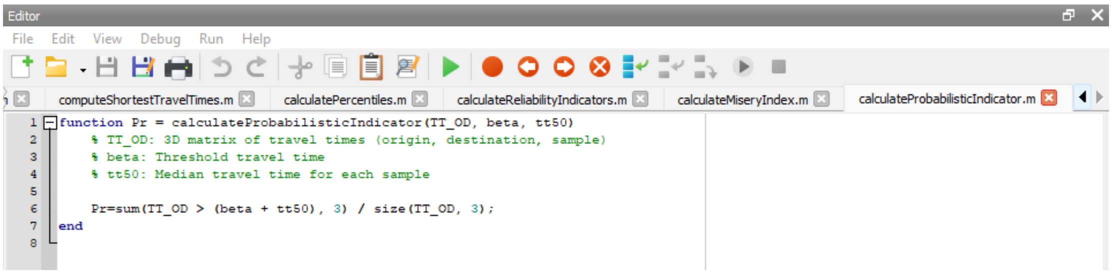
Regular Users:

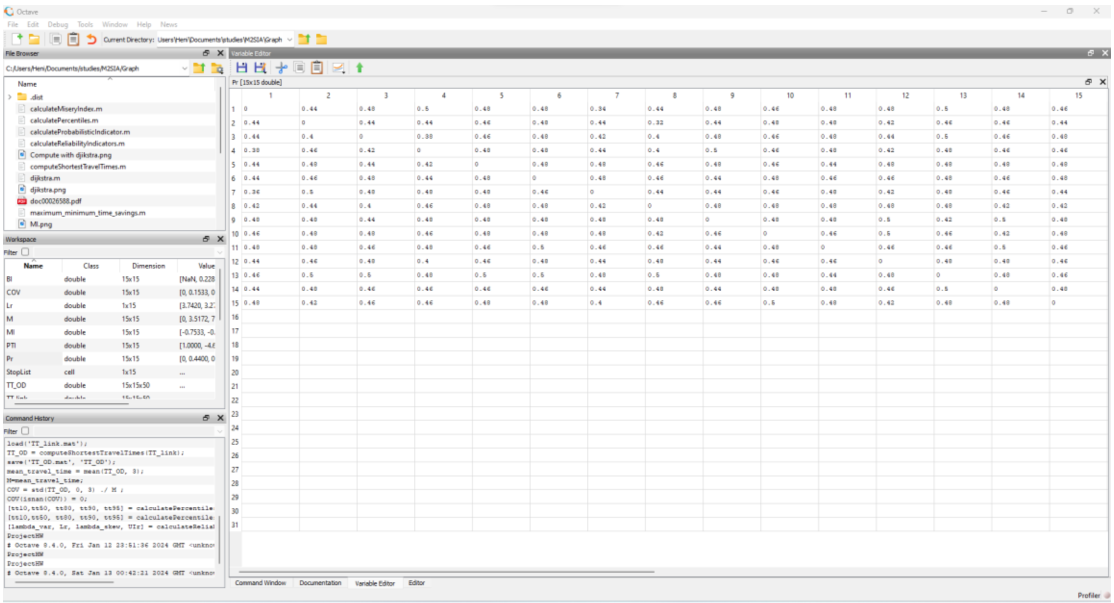
Look for stability and smaller gaps in Misery Index values, indicating a more consistent and predictable experience.

Occasional Users:

Pay attention to extreme negative values, as they might suggest more favorable conditions for the least fortunate travelers.

Compute Pr:





Regular Users:

May be interested in higher probability values (closer to 1), as this indicates a higher likelihood that travel times will not deviate significantly from the median.

Higher probability values suggest a more predictable travel experience with lower chances of encountering unexpected delays.

Regular users may appreciate consistent and reliable travel times, and thus focus on assessing the reliability reflected in the higher PR values.

Occasional Users:

Might be interested in the variability of the PR values, looking for situations where the probability is lower (closer to 0).

Lower probability values indicate a higher likelihood of deviation from the median, which might be crucial for occasional users who are less familiar with potential travel uncertainties.

Occasional users may be more concerned about potential delays and might want to be prepared for variations in travel times.

Conclusion:

Regular Users:

Seek higher PR values for a more reliable and consistent travel experience.

Occasional Users:

Observe variations in PR values, focusing on lower probabilities that indicate potential deviations from the median travel time.

7.INTERPRETATION:

As a regular user, indicators like BI (Buffer Indicator) and PTI (Planning Time Index) would be crucial. These indicators help users plan for uncertainties and ensure on-time arrival, considering both buffer time and planning time.

An occasional user might be more concerned with extreme travel time delays. Hence, indicators like MI (Misery Index) and Pr (Probabilistic Indicator) could be of interest to gauge the likelihood of encountering significant delays.

Overall, the choice of the most relevant indicator depends on the user's priorities. Regular users may prioritize efficient planning, while occasional users may be more concerned with avoiding extreme delays.

8.MAIN PROGRAM:

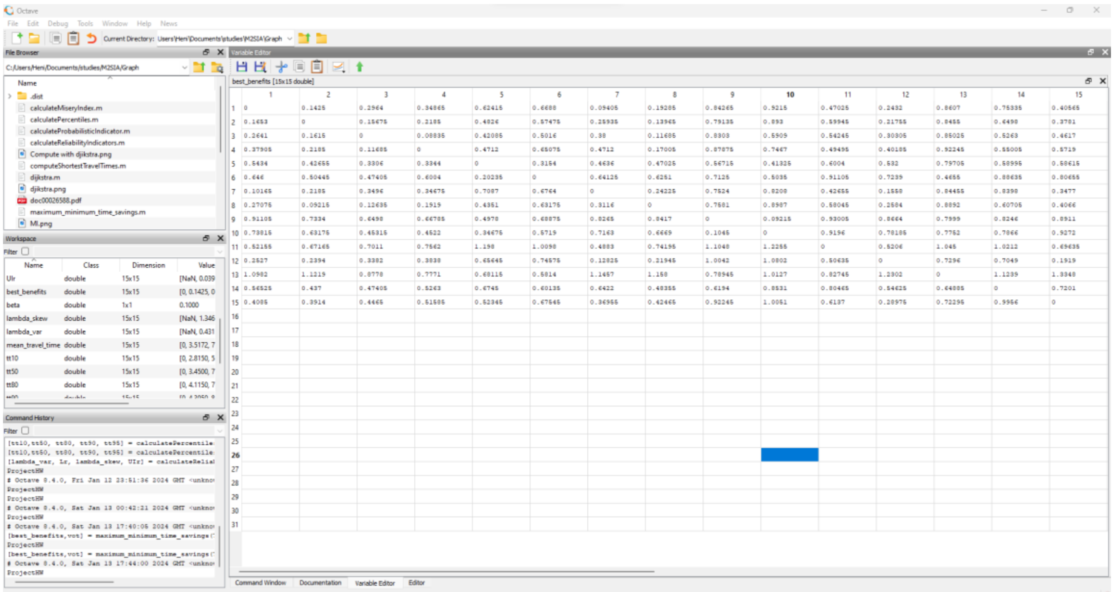
```
% Load the travel time matrix from the TT_link.mat file
load('TT_link.mat');
TT_OD = computeShortestTravelTimes(TT_link);
% Save the TT_OD matrix to a file
save('TT_OD.mat', 'TT_OD');
% Compute mean travel time (M)
mean_travel_time = mean(TT_OD, 3);
M=mean_travel_time;
COV = std(TT_OD, 0, 3) ./ M ;
COV(isnan(COV)) = 0;
[tt10,tt50, tt80, tt90, tt95] = calculatePercentiles(TT_OD);
[lambda_var, Lr, lambda_skew, UIr] = calculateReliabilityIndicators(tt10, tt50, tt90,tt95, TT_OD);
BI = (tt95 - M) ./ M;
tt_freeflow=tt95;
PTI = tt95 / tt_freeflow;
MI = calculateMiseryIndex(TT_OD, tt80, M);
Pr = calculateProbabilisticIndicator(TT_OD, beta=0.1, tt50);
[best_benefits,worst_benefits,vot] = maximum_minimum_time_savings(TT_OD,tt50);
```

II. Value of time

Compute maximum and minimum time savings benefits in the worst and best situation:

```
function [best_benefits,worst_benefits,vot] = maximum_minimum_time_savings(TT_OD,tt50)
    vot = 11.4/60;
    best_benefits = (tt50-min(TT_OD,[],3))*vot;
    worst_benefits = (tt50-max(TT_OD,[],3))*vot;
end
```

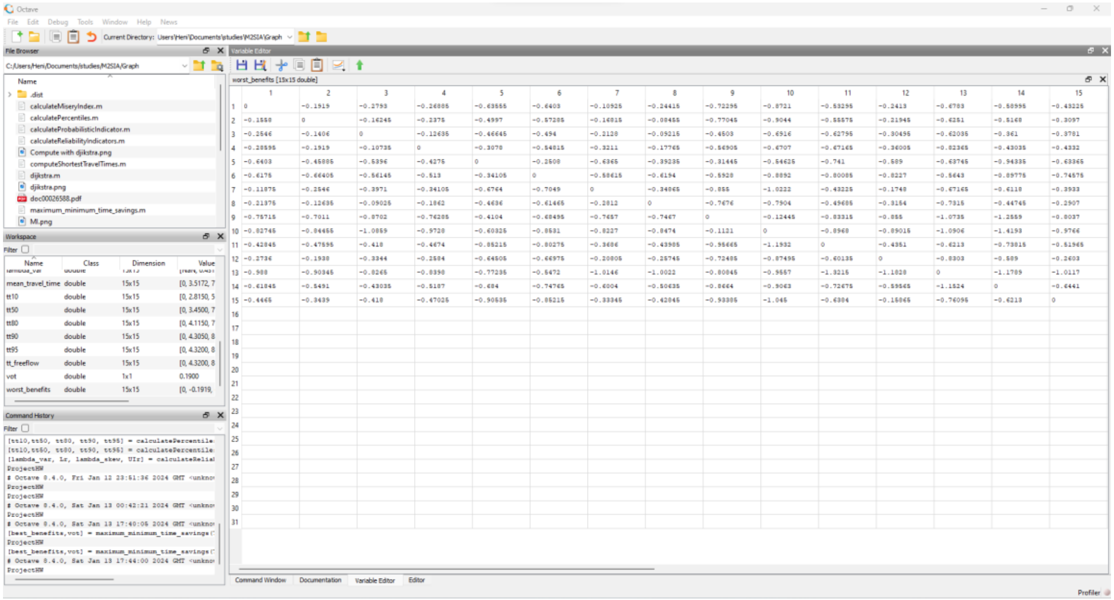
Best Benefits:



Highest value: 1.3348

Lowest value: 0.08835

Worst Benefits:



Highest value: -0.084550

Lowest value: -1.4193

```
>> fprintf('Maximum value (excluding 0): %f\n', max(best_benefits(worst_benefits ~= 0)));
Maximum value (excluding 0): 1.334750
>> fprintf('Minimum value (excluding 0): %f\n', min(best_benefits(worst_benefits ~= 0)));
Minimum value (excluding 0): 0.088350
>> fprintf('Maximum value (excluding 0): %f\n', max(worst_benefits(worst_benefits ~= 0)));
Maximum value (excluding 0): -0.084550
>> fprintf('Minimum value (excluding 0): %f\n', min(worst_benefits(worst_benefits ~= 0)));
Minimum value (excluding 0): -1.419300
>> |
```

Worst Scenario (Negative Values):

- Negative values indicate a decrease in time-savings compared to the initial conditions.
- Users may experience delays or longer travel times in the worst scenario.
- In the worst scenario, there is a notable increase in travel time, leading to potential monetary waste for users.
- Reliability issues and unpredictability can result in inefficiencies, possibly impacting work schedules, appointments, and overall productivity.

Best Scenario (Positive Values):

- Positive values indicate an improvement in time-savings compared to the initial conditions.
- Users may experience shorter and more efficient travel times in the best scenario.
- The best scenario presents an opportunity for users to save time and potentially reduce monetary waste associated with delays.

- Reliable and efficient travel times contribute to better time management and increased productivity.

Overall Analysis:

Monetary Impact:

The worst scenario suggests a potential negative impact on users' budgets due to increased travel time, affecting both personal and professional aspects.

The best scenario indicates potential cost savings as users experience more efficient travel times, leading to less monetary waste.

Implications:

The reliability of travel time plays a crucial role in minimizing monetary waste associated with delays.

Infrastructure improvements or better traffic management can contribute to more positive scenarios, reducing the economic cost of travel for individuals and businesses.

User Experience:

The monetary implications are directly linked to the overall user experience, emphasizing the importance of reliable transportation systems for economic efficiency.

Conclusion

In conclusion, addressing factors that contribute to the worst scenarios, such as traffic congestion or unexpected delays, can significantly reduce the monetary waste of time for travelers and enhance the overall reliability of transportation systems.